NASA-CR-203737

Second Annual Progress Report

for

NASA Grant **NAG5-2838**

for

University of Minnesota

Data Analysis of the WAVES Experiment

for the period
from 1 January 1996
to 31 December 1996

Professor Paul J. Kellogg
Keith Goetz
University of Minnesota
School of Physics and Astronomy
Plasma Waves Lab
116 Church Street S.E.
Minneapolis, MN 55455

Summary

This grant was awarded to the team led by Professor Paul J. Kellogg to provide support for the University of Minnesota data reduction and analysis effort for data produced by the WAVES instrument. The WAVES instrument was launched on the WIND spacecraft on November 1, 1994. Beginning after its initial commissioning and check-out phase was completed, this grant has provided funding for all University of Minnesota WAVES data analysis.

The University of Minnesota, in cooperation with other WAVES team members at the NASA Goddard Space Flight Center, the Paris Observatory, the Naval Research Lab and Queen Mary College, London, have collected and analyzed all available WAVES data. Numerous presentations and publications have been made. Efforts continue to correlate results from WAVES with other experiments on WIND as well as experiments on other spacecraft.

After several passes through the shadow of the moon we have, along with our WIND colleagues, redefined the picture of the plasma environment surrounding the moon.

As we continue to build on the existing WAVES data-set, the University looks forward to a long lifetime in orbit for the WAVES experiment and continued opportunities for scientific research.

WAVES Data Acquisition

The University has acquired all WAVES level-0 telemetry data during the second year of the WIND mission. In addition to the WAVES data, Key Parameter (KP) data from the other WIND investigations has been collected when available. Spacecraft orbit and attitude data have also been collected. Typically, one file of each of these classes of data is generated per day. These files have been collected and stored on-line on the Lab's computer system such that all WIND telemetry is available on-line at all times.

With each new day of data, the Minnesota team has processed the data to ensure the continuing health and safety of the WAVES instrument. Several anomalies were found during the second year which required recovery action on the part of the WAVES team. It is essential that this health and safety monitoring be done in the timely manner in which it has been done during the first two years.

The WAVES level-0 data received each day has also been examined scientifically. Each day the Lab produces a number of standard data products (graphs) for that day's data in order to quickly summarize the scientific data during the day and indicate interesting periods for further analysis.

Instrument Commanding and Operations

In addition to the reception and analysis of scientific and housekeeping data, the WAVES instrument requires a detailed commanding schedule which must be defined and submitted to the WIND Flight Operations Team (FOT) well in advance of the observations. The merging of science requirements into the observation schedule must be done to produce the maximum scientific return. These command schedules, microprocessor uploads and observation coordination were performed at Minnesota during the first and second years of the WIND mission and will continue to be done at Minnesota during the third year.

The WAVES team normally generates more commands than any other instrument on the WIND spacecraft and, as such, instrument commanding is an important function to which we pay close attention.

When the WAVES spin axis (Z) antenna deployments were initially done (in late 1994), the deployed length was restricted to only 80% of the available length for reasons of spacecraft stability. As WIND spacecraft operations proceeded, the stability danger diminished until this limitation was withdrawn. Toward the end of 1996 we revisited the plans and procedures for antenna deployments along with the GGS FOT. On November 20th we successfully deployed both the plus and minus Z antennas to their full length of 5.28 meters. This additional length increases the size of our received signals and therefore the scientific return from the WAVES instrument.

Flight Software

The WAVES instrument was designed to allow flight software modifications to change the operational mode of its various subsystems during flight. During the second year, several important changes to the flight software were made. These software changes consist of new program units which are written at Minnesota and converted into memory load streams which are sent to the GGS Flight Operations Team for uploading to the spacecraft.

Early in the year, the event selection software for the Time Domain Sampler (TDS) was changed to allow it to save more interesting events in its on-board memory for later transmission to the ground. Now, when a burst of solar activity generates a long series of interesting events, the TDS retains many of the best events and sends them to the ground as space in the telemetry stream allows. This means that a long time can pass between the time the event was collected and the time it is received on the ground. The oldest event so far received waited 4 and one half days in the TDS' memory before being sent to the ground.

One of the WAVES team members (Reiner) proposed a new operating mode for the RAD1 receiver in order to improve direction finding of solar bursts. This mode was coded and uploaded and is to be used whenever the spacecraft is within 150 earth radii of the Earth. In addition to the changed flight software, changes were required in the ground software (WINDlib) to allow access to the differently structured science data.

Another interesting opportunity occurred late in the year when the WIND spacecraft came into the range of several earth based radar facilities. A member of the WAVES team (Rodriguez) proposed reconfiguring the RAD2 receiver to allow WAVES to receive the signals from these ground based transmitters. Again, the flight and ground software were modified and the radar campaign was a success.

Ground Software

Before the launch of the WIND spacecraft, the University of Minnesota, along with collaboration from the broader WAVES team developed a library of data access tools for use with the WAVES instrument. During the second year of the WIND mission, that software has been maintained and updated on a number of platforms where it is in daily use by many WAVES team members around the world. In addition to enhancements and maintenance, it was also ported to several new systems.

The GGS/POLAR spacecraft was launched in February of 1996, during the second year of the WIND mission. POLAR instruments produce a number of Key Parameter (KP) files which can be used to allow the WAVES team to make correlations between observations made on WIND and observations made on POLAR. The earlier GEOTAIL spacecraft also produces KP files of observations made from its orbit. WINDlib was modified to allow users to access the various scientific quantities from both POLAR and GEOTAIL at the same time data from the WAVES instrument on WIND are examined.

During the second year, several changes and additions occurred in the KP data products. WINDlib modifications were sometimes required in order to give the WAVES team continued access to the data.

At the time of the launch of WIND, the WAVES team maintained ground support equipment (GSE) in the GGS Payload Operations and Control Center (POCC) at GSFC. This computer system was used from time to time for real-time access to data from the WAVES instrument. Real-time access is especially important when there are instrument problems and when doing memory loads. Early in the second year it was decided that the POCC could no longer accommodate our resident GSE. Because real-time access can be important, we modified WINDlib to allow any user with internet access to use *near* real-time data served by the Command and Data Handling Computers at GSFC. This conversion has allowed us to maintain near real-time support for the WAVES instrument without having a physical presence at the POCC.

WINDlib is also used by the GGS CDHF computer system in the generation of the WAVES Key Parameters. As such the software library was updated several times on the CDHF computer.

Early in the second year the WAVES team decided that the existing WAVES Key Parameters (KPs) were inadequate for the scientific community at large. To correct this problem we participated in redefining the WAVES KP generation software and eventually certified the WAVES KPs for public distribution.

In addition to the continued evolution of WINDlib, a tool for data access, the Lab has also worked to develop and evolve a number of computer programs and techniques for the analysis and display of WAVES data from a scientific point of view. This involves a number of routines to produce line graphs and spectrograms of WAVES data.

Areas of Scientific Interest

It was formerly thought the wake of the moon was a single ion depletion region in the solar wind as it is absorbed by the non-magnetic moon. It is now understood that there are electron density wings streaming off in along the interplanetary magnetic field lines. These wings correspond to regions of electron depletion. As a result, currents must flow to fill in the depleted regions which gives rise to waves measured by the WAVES experiment. The **lunar wake** is a much more interesting place than had been thought.

This year we began a thorough investigation of the **turbulent layer** in the earth's bow shock. So far it has been found that the turbulence is short wavelength and high frequency so that electrons are unmagnetized. Nevertheless the turbulence is not simply one dimensional but is elliptically polarized. Along these lines we began a collaboration with Ron Lepping (of the MFI experiment) on this and presented paper at Fall AGU on these results. Interestingly, we have now found similar effects in interplanetary shocks.

We have also started an investigation of waveforms in so called **ion acoustic waves** in the solar wind. These are also found to be elliptically polarized

Work continues concerning **foreshock waves**. We recently began a collaboration with Dr. Martin Goldman (of the University of Colorado), on foreshock Langmuir waves. He initially expressed an interest in WAVES TDS data and is providing his simulation talents. Langmuir waves are also not always one dimensional. We have found pretty clear evidence for 3-wave parametric decay, but evidence for modulational instability is uncertain.

Some calculations were made, using the antenna modeling software, ESP4 from Ohio State University, of the **antenna patterns** of WIND. The pattern of the Y antenna is somewhat distorted by the magnetometer and search coil booms. The pattern was measured by Bob Manning using a model in a fluid tank, and the results are similar, but not exactly equal. We communicated these results to a Russian group which is collaborating in making observations using a powerful ground based radar.

Graduate Student

A graduate student, Scott Doudrick, has continued working on the magnetic noise burst problem. Using data from the low frequency FFT and the slow speed TDS, he has developed software to determine the direction of propagation as well as the polarization of these waves.